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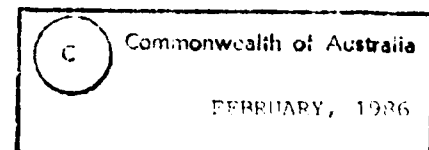
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RADHAZ IN THE E AND A AREA

R. Czigledy

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An assessment is made of the probable level of r.f. Radiation hazard, Radhaz, generated in the Physical Chemistry Division of MRL by a transmitter operating in the neighbouring Engineering Design Establishment (Maribyrnong).

The proposed transmitter would have a power output of 1000 watt and operate at frequencies from 2 MHz to 30 MHz. An assessment has been made of its induced effect on detonator leads.

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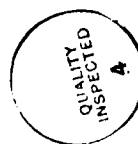
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ABSTRACT

An assessment is made of the probable level of r.f. Radiation hazard, Radhaz, generated in the Physical Chemistry Division of MRL by a transmitter operating in the neighbouring Engineering Design Establishment (Maribyrnong).

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C O N T E N T S

RADHAZ IN THE E AND A AREA

1. INTRODUCTION

The use of explosives within a strong radio frequency (r.f.) environment has normally led to the implementation of stringent and complex safety requirements. This has especially been highlighted in the commercial field where sensitive electric detonators, with long connecting wires, are the normally available item. Until recently the Explosive Research and Development Groups of MRL have been fortunate to have been located in a relatively radio frequency free environment, however a neighbouring establishment (Engineering Design Establishment), now requires to install and use a 1000 watt transmitter which will operate in the frequency range of 2-30MHz.

The electromagnetic field generated by such a transmitter will affect a circular surrounding area and the strength of the field at any point will theoretically depend on the square of the distance from the transmitter and the radiated aerial power. The Physical Chemistry Division of MRL lies adjacent to EDE and will consequently be exposed to a r.f. field strength of moderately high intensity.

Any length of wire or cable exposed to electromagnetic radiation will act as a receiving aerial and will absorb energy and direct it to any device connected to that cable. Should the level of induced energy exceed the threshold no-fire level of an electro explosive device (EED) it could cause an inadvertent initiation. Designers of military stores using an EED for the initiation of an explosive are aware of this "Radhaz" problem and provide protection for the EED in the form of shielding and filters. However often in an explosive R&D laboratory environment a device relying upon electrical intiation must be prepared, handled and tested without r.f. protection. It is not uncommon that during the test period of a device it is connected to unshielded firing leads which may be typically between five to thirty metres long.

1

It is possible that an EDE transmitter could be located less than 40 metres from a number of Physical Chemistry Division (PCD) buildings where EEDs are likely to be present. These buildings are 505, 671, 675, 914, 1072 and 1078.

Although it is difficult to define precisely the conditions under which an EED is hazardous, any assessment of Radhaz must be based on the theoretical level of r.f. energy that can be induced in a device as a function of power of the transmitter and its distance from the device. For comparison the susceptibility to r.f. of two typical EEDs is considered and, for the purpose of this exercise, they are assumed in each case to be connected to 5 and 30 metre firing leads. The mathematical basis for the theoretical assessment of their performance is the "Principles of Design and Use for Electrical Circuits Incorporating Explosive Components" which is an enclosure to OB PROC 41273.

2. FIELD STRENGTH GENERATED BY TRANSMITTER

The field stength S, at any point within an electromagnetic field can be expressed by,

$$S = GP/4\pi d^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

This equation expresses field stength S as a function of the r.f. power P applied to the transmitting aerial. By using this terminology we can eliminate all parameters associated with the efficiency of r.f. generation and transmission system. The aerial gain G takes into account the type of antenna used and, because of the relatively short distance d from the aerial to the explosive device, the generated radiation field is assumed to be symmetrical.

The proposed aerial is to be an omnidirectional half wavelength dipole which has a typical power gain of 1.6 over the operating frequency range. The field strength around the proposed 1000 watt transmitter is calculated using equation 1 and is shown in figure 1. The results are presented for a flat linear range of 40 m to 240 m and measured from the base of the aerial. The two values of radii encompass that area within MRL where the use of unshielded EEDs are most likely to be found.

3. RADIO FREQUENCY POWER PICKUP

The induced power Pi in an aerial subjected to an r.f. field is related to the effective area of the aerial Ar, and the field strength at that point is expressed by:

$$Pi = Ar \ S \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (2)$$

where $\quad Ar = \dfrac{Gr \ \lambda^2}{4\pi}$

where Gr is the gain of the receiving aerial.

By substitution we can arrive at an equation to derive a value for the induced power as a function of those parameters that can be physically measured. Therefore,

$$Pi = \dfrac{S \ Gr \ \lambda^2}{4\pi} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3)$$

The induced power in a receiving aerial will be a maximum at that frequency fm where the physical dipole length ℓ of the aerial is equal to half the wavelength λ of the transmitted frequency.

The general equation (3) gives a practical mathematical solution for both this condition and for those frequencies above fm where the calculated value of $\lambda/2$ is less than the physical length ℓ of aerial dipole of the receiver.

However at frequencies below fm the receiving dipole length is much shorter than the value calculated by $\lambda/2$. Under these conditions the equation must be modified to allow for the fact that a practical receiver dipole can see only a small section of the radiated half wave length. Consequently the amount of power capable of being induced in the aerial is reduced in proportion to the reduction of physical aerial length. The reduced power level can be represented by the equation.

$$Pi = \dfrac{S \ Gr \ \ell^5}{4\pi \ (\frac{\lambda}{4})^3} \quad \ldots \ldots \ldots \ldots \ldots \ldots (4)$$

For a power level acceptable to the safe handling of a particular device, defined as P_p, equations (3) and (4) can be rearranged to obtain the maximum permissible field strength Sp in the radiation field. The permissible field strength equations for the two sets of circumstances are as follows:

Case 1.   Where the transmitter frequency is equal to or greater than fm, that is $\lambda/2$ is equal to or less than ℓ .

$$Sp = \dfrac{4\pi \ P_p}{Gr \ \lambda^2} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (5)$$

Case 2.   Where the transmitter frequency is less than fm, that is $\lambda/2$ is greater than ℓ .

3

$$Sp = \frac{4\pi \, P_p}{Gr} \cdot \left(\frac{\lambda}{4}\right)^3 \cdot \frac{1}{\ell^5} \quad \ldots \ldots \ldots \ldots \quad (6)$$

4. LEAD CONFIGURATION AND EED CONSIDERED

The aerial that makes up the receiving dipole for the EED essentially consists of two sections:

(a)   The leads permanently attached to any explosive device. Wire lengths ranging from 1 m to 4 m are not uncommon with either commerical or military detonators or explosive filled devices.

(b)   The additional leads which may be used in conjunction with the device leads to connect the device to a remote firing system.

The total length of the firing leads can therefore vary between one and thirty metres depending on the device and its application. The dipole lengths that provide maximum energy pickup at the frequency limits of the transmitter (2 MHz and 30 MHz), are 75 m and 5 m respectively. Any lead length between these limits will provide maximum energy pickup for the frequency where the half wavelength of the transmitted frequency is equal to the cable length. The energy pickup decreases as the frequency moves away from the lead length to 0.5 λ ratio giving rise to a family of susceptibility curves for each length of lead.

As stated earlier, expected lead lengths will be between one and thirty metres. The upper limit of transmitter frequency has a 0.5 λ length of 5 m and below this length the pickup will decrease. Based on this, the limits of dipole lengths used to calculate the permissible field strength levels were selected at 5 m and 30 m.

The two types of EEDs selected for examination were devices having different modes of functioning. One unit was a conducting composition (CC) cap and the other a hot-wire fuze head . The characteristics of each device which are relevant to this exercise are shown in table 1.

TABLE 1

Characteristics of EEDs used in calculations

Unit	No-fire threshold		Resistance
	Energy	Power	
18V, CC Cap	35 µJ	64 mW	20-250 ohm
F53 Fuzehead	2.3 mJ	80 mW	0.9-1.6 ohm

4

5. CALCULATIONS OF SAFE DISTANCES

Explosive device design requirements are that the energy picked up by a device may not exceed a level 10 dB below the no-fire threshold level for the average EED and reduced to 7 dB below the no-fire threshold level for EED with well documented characteristics.

For the purpose of this assessment the no-fire threshold level was chosen as the reference level of the permissible induced power. The field strength/frequency characteristics of the two devices were determined using equations 5 and 6 and are shown in figure 2. The safe field strength areas are those enclosed by the "V" for a particular device connected to the indicated lead lengths. Thus for a frequency of say 10 MHz the maximum safe field strength that can be tolerated by a F53 igniter is 7×10^{-3} Wm^{-2} when connected to a 30 m dipole and 10^{-1} Wm^{-2} when connected to a 5 m dipole. The corresponding safe distances can now be determined from figure 1 and are 133 metres and under 40 metres respectively.   The field strength corresponding to any level of required attenuation may be obtained by reducing the calculated no-fire field by the desired dB level.

6. DISCUSSION

The characteristic curves of figure 2 indicate that the field strength required to exceed the no-fire threshold level power in a CC cap EED connected to 5 and 30 metre leads is 5×10^{-2} and 3.2×10^{-4} Wm^{-2}. The field strength/distance curve of figure 1 shows that such an EED must be at a distance of 160 metres from the transmitter when connected to a 5 metre lead and in excess of 240 metres when connected to a 30 metre lead. The theoretical separation distance at which the field strength is down to the 3.2×10^{-4} Wm^{-2} level was calculated to be 611 metres.

The no fire power level of the less sensitive F53 hotwire igniter is induced by field strengths of 7.7×10^{-2} and 5.3×10^{-4} Wm^{-2} for the 5 and 30 metre lead configurations. The transmitter/EED separation distance corresponding to a field strength of 5.3×10^{-4} Wm^{-2} was determined as 155 m and 41 m for the 7.7×10^{-2} Wm^{-2} strength.

The foregoing indicate that in the event of the proposed transmitter becoming operational, a number of laboratories within the E&A area will theoretically be subjected to r.f. radiation having a field strength between 0.06 and 0.08 Wm^{-2}.

The less sensitive of the EEDs considered (the F53 hotwire igniter), when connected to 5 m leads and subjected to the above r.f. field, would not be safe in the perimeter buildings 505, 671, 675, 914 and 1078. The 18 V CC caps could only be used with 5 m leads in the firing chambers of building 666.

One problem highlighted by this study and not capable of being adequately defined occurs during the development and preparation of experimental detonators. The philosophy of EED classification assumes that the firing characteristics of the device under consideration have been previously established and hence the device is safe when subjected to an r.f. energy input 10 dB below the well know and defined no-fire level. Initially a limited number of test firings may be scheduled to occur concurrently with the development of an EED and this may indicate the region in which the devices no-fire threshold condition occurs. However, the margin of safety supposedly provided by the -10dB step may not be sufficient to ensure that an inadvertent functioning of the explosive filled device does not happen.

It must be stressed that the results presented in this study represent only a theoretical assessment of a device's susceptibility. A true or more practical approach to the safety of handling EEDs can only be obtained after measurements of actual field strengths are made throughout the area while a representative transmitter is operating. The field strength at any point within the area under consideration will be attenuated or enhanced by its topography and the location and type of buildings. Although the buildings within the affected area are in general not r.f. protected, their structural components can provide some degree of r.f. attenuation which may not have been taken into consideration. The greatest probability of r.f. induced intiation will occur at that time when an unprotected EED is attached to firing leads outside such a building.
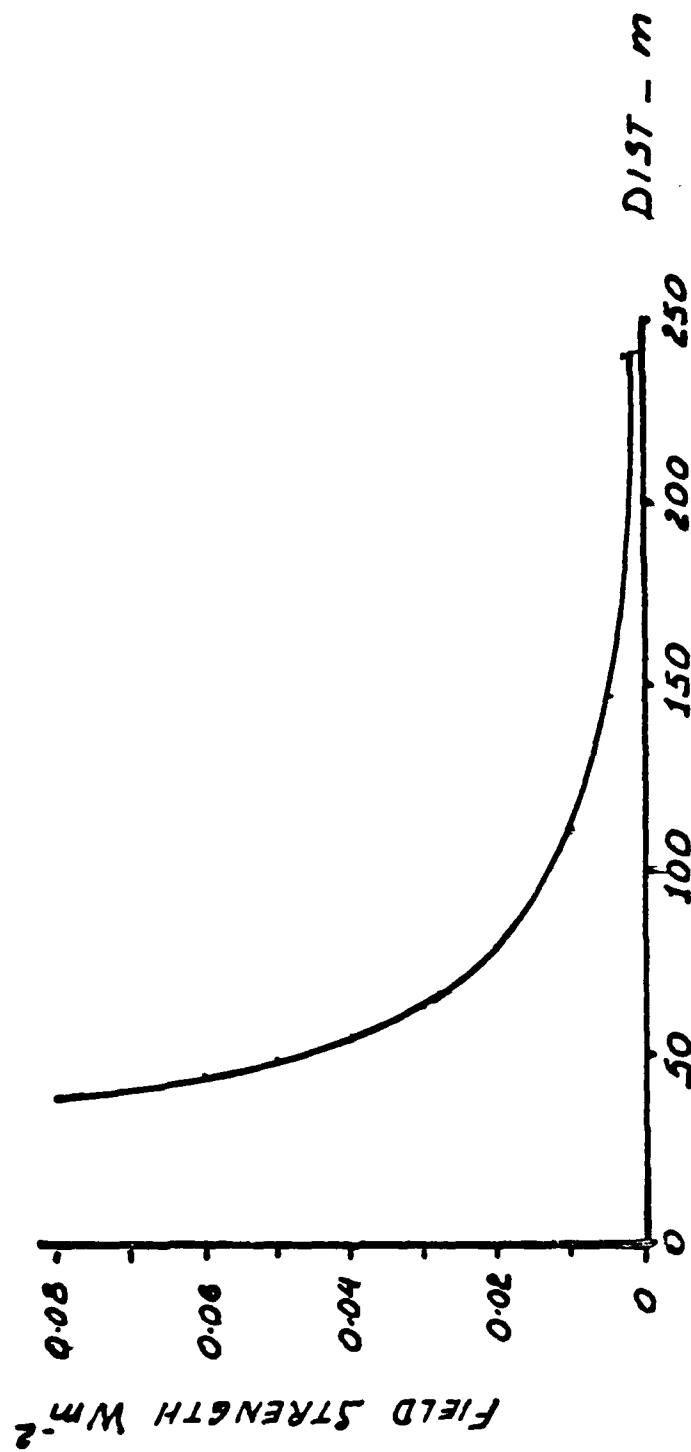
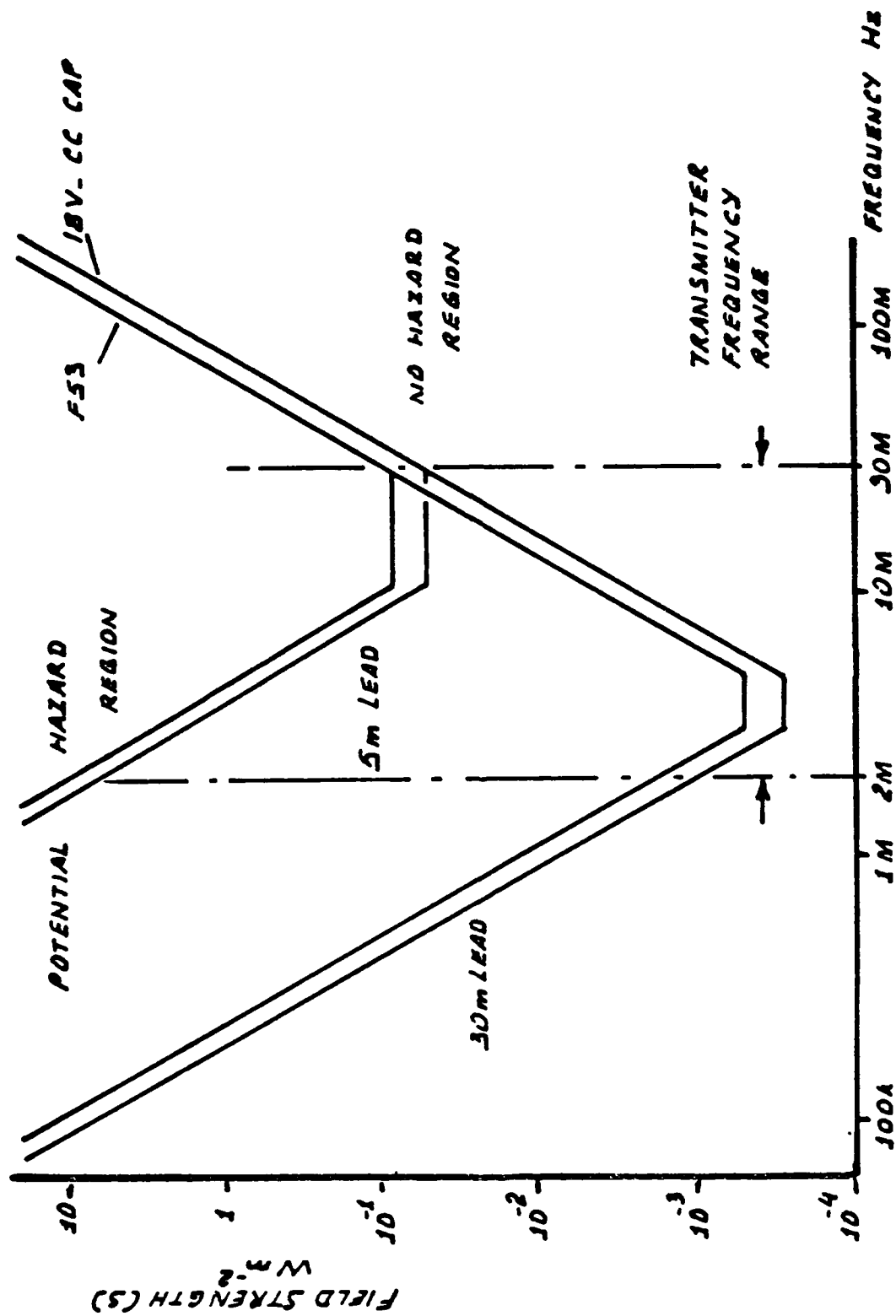FIGURE 1. Field Strength Around 1000 W Transmitter

FIGURE 2. Field Strength - Frequency Characteristics of Typical EED Connected to 5 and 30 m Leads

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